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Agricultural Research

Feeding Tomorrow's Billions

America's agricultural bounty, unparalleled in history, rests on research that helps make our farms productive despite a host of uncertainties and unknowns.

Some events, such as sieges of bad weather or devastation by insects, have shadowed farmers and diminished harvests since ancient times. In recent times other problems have surfaced. Experts are concerned, for example, that much of our natural resource base is in trouble. Almost half the Nation's original topsoil has eroded. Groundwater has been heavily mined for irrigation. If not corrected, these problems can only intensify within the next 20 to 30 years.

Other constraints on food production include the high costs of oil and natural gas and the products made from them, such as fertilizer; overused rangelands; and polluted air and water. A backdrop to all these problems is the sobering reality that after years of often spectacular gains in harvests, yields of key crops have peaked or are flattening out.

"Basic research remains our best insurance against the unknowns that threaten productivity," says Terry B. Kinney, Jr., administrator of the Agricultural Research Service. A major goal of the agricultural research community, he says, is to help win the looming race between population and the plow. It is predicted that by the year 2020, there will be 8 billion more people worldwide to feed, almost 100 percent more than today.

Among the promising research approaches toward helping meet future world food needs—conquering hunger and malnutrition—is the study of familiar and lesser known plants as food sources. A vast potential for exploitation awaits in the plant kingdom. Of the more than 300,000 species of identified plants, only 150 appear regularly in the human diet. In some countries only one staple—rice, wheat, corn, or potatoes—constitutes the basic diet.

Kinney says basic research that significantly extends the shopping list of foods could gain at least three tactical advantages for the worldwide struggle to feed more people:

- If a staple crop were damaged by drought or disease, new food crops could help replace the reduced or lost nutrients.
- If the growth rate for agricultural productivity held—now 1.3 percent annually—but population boomed, new crops that yielded more per acre or filled unexploited ecological niches could help close the gap.
- As the supply of arable land relative to people diminishes, new high-yielding crops could provide both needed variety in the diet and produce more nutrients per acre.

In the long run, success in the struggle to feed more people calls for more fundamental knowledge in the domain of biology. Especially high hopes, whose fullfillment may be some years away, are vested in research projects probing the mysteries of two all important natural processes: photosynthesis and nitrogen fixation. Plants harness less than 1 percent of the sunlight falling on their leaves as they photosynthesize carbon dioxide and water into the sugars upon which life depends. It would be a monumental research achievement to find a way to improve this low rate of photosynthetic efficiency, and open the way to raise crop yields. Some researchers say the increase could be as much as 45 percent.

The ability of a plant to capture and fix nitrogen from the air for its own use is limited now to such legumes as clover and alfalfa. Genetic engineering may provide the means to incorporate this ability into rice, corn, wheat, and other dietary mainstays. Designing staple crops that can supply their own nitrogen would cut the heavy current usage of oil and natural gas in the manufacture of fertilizer.

Significant advances and several on-the-farm applications have been registered on another biological front. Life-regulation chemicals produced by plants themselves—bioregulators—are influencing a wide range of plant growth processes. For example, a bioregulator could slow the aging process of the soybean plant so that the pods develop more fully. Or one could direct the soybean plant to channel energy from photosynthesis to producing seeds instead of leaves. Not only can bioregulators raise yields, they also improve the quality and nutrient level of crops. The fruit industry now uses them to promote uniform fruiting and to retard the ripening process that leads to spoiling in storage. Still other benefits from bioregulators are within reach.

Despite research achievements and prospects, questions concerning whether there will be enough food to feed tomorrow's billions often engender deep pessimism. But optimism is called for. The complex of today's technologies has given rise to a new resource—technology itself—that generates "science power." Unlike natural resources, technology is manmade. "Basic research takes time," cautions Kinney, "so research results do not move overnight from the lab to the furrow and farrowing house. But steadiness and creativity in harnessing science power will gain the fundamental knowledge we need to remedy many of the problems, uncertainties, and unknowns that beset agriculture today. If we share with our neighbors abroad the research knowledge we have been gaining for a century and more, all of us will eat."■

R.P.K.

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Cover: ARS biologist Dennis Johnson collects rust spores from musk thistle—one of the weeds which he and his colleagues at USDA's Plant Disease Research Laboratory in Frederick, Md., are working to control through the use of imported plant pathogens. Article begins on p. 8. (02582W487-15)

Correction: The caption to the photograph on p. 6 of the October 1982 issue should have read that one undamaged musk thistle plant can start more than 3,800 seedlings. One undamaged flowerhead may produce up to 1,500 seeds.

Lean and Fat Pigs Provide Insights

A semiliquid diet fed through a surgical opening, monitored by physiologist Jerome C. Pekas, is helping scientists study various gastrointestinal processes related to feed efficiency in pigs. (0882X937-9)

Genetically lean pigs produced up to 45 percent more lean meat than genetically obese pigs that consumed the same amount of feed and reached the same slaughter weights in the same amount of time in research at the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebr.

A breeding line of lean pigs and another line of obese pigs that were used in the study were both selected through many generations from the same ancestors.

"A slightly larger percentage of the obese live weight was hung in the cooler as resalable carcass," says ARS physiologist Jerome C. Pekas, "but once the fat and bone were trimmed out the obese pig didn't hold a candle to the lean pig."

Pekas studies the gastrointestinal (GI) tract in these pigs. He says the role of the GI tract in animal performance and its interaction with diet, when better understood, might explain differences between superior and inferior animals.

In the conventional vocabulary of farmers and animal scientists, superior performance means better than average weight gain and feed efficiency or amount of gain per pound of feed.

"A decade from now we'll probably have much more sophisticated criteria for selecting breeding stock for efficient production of lean meat," says Pekas. "Ideally we would like to identify superior breeding animals as early in their lives as possible."

Continued probing for answers may pay handsome dividends for producers and consumers of pork. The obese and lean swine lines now maintained at the Center were first selected by geneticists at the Beltsville Agricultural Research Center, Beltsville, Md., 15 years ago. Some of the animals are now up to 25 generations removed from the original ancestors.

Now, scientists from diverse disciplines are working together in teams with these lines to solve the riddles of fat synthesis.

"We're each pursuing different questions with the same animals and that makes the data so much more meaningful," says Pekas. "I think that as we study these animals we're going to find a lot of differences between lines."

Lipid biochemist Harry J. Mersmann of the Center's Meats Laboratory is studying an ultrasonic technique for measuring fat thickness in live animals. This technique someday may be used routinely. The scientists say backfat thickness is not necessarily a perfect indication of an animal's fat and lean composition, but backfat measurement is at least a big step in the right direction.

"I think we could make much quicker progress in selecting animals for leanness if we could do it by some means other than through multigeneration studies," says Mersmann. "For example, if we knew biologically why an animal doesn't deposit much fat, we might be able to

select animals directly from some biochemical substance in the blood or in a small tissue sample."

Progeny testing, which presently involves carcass studies on a number of animals, is expensive, Mersmann says. While praising the progress animal breeders have made, he indicates more rapid and direct progress could be made by selection for metabolic parameters directly involved in protein or fat deposition. In keeping with this, he is studying cell breakdown and synthesis in the obese and lean swine lines.

Mersmann and ARS nutritionist Wilson G. Pond found that the obese lines had no higher blood cholesterol or triglyceride levels than the lean pigs. High levels of these blood constituents are associated with debilitating diseases such as heart disease and diabetes in humans.

In studying various animals—pigs, sheep, cows, and rats—scientists are finding vast differences in their physiologies. By making comparisons among animals, researchers at the Center may provide insights helpful to humans although that is not a main purpose of studies at the Center.

Pekas says meat animal scientists have made particularly significant contributions in studies on hormones involved in human and animal reproduction. In studies on the digestive tract, however, animal scientists are lagging, probably because animal subjects do not readily communicate that they have a bellyache or a slight case of indigestion.

Pekas is focusing on the GI tract of the two lines because he says the digestive tract stands between all the feed consumed and all of the body performance of the animal.

In one study, the scientists fed the pigs a diet made high in fiber with alfalfa meal. At slaughter time the lean pigs' small intestines and colons were almost half again as heavy as the colons from obese pigs. Weight per unit of length of the intestines increased in both types of animals, indicating they got thicker. In the lean pigs the length of the intestines remained the same as when fed a normal diet, but the weight increased. Obese pigs did the opposite—the length decreased but the weight remained the same.

"I don't know if this discovery is physiologically important, but such unexpected findings cause one to look at the GI tract and ask questions," says Pekas. "What causes the digestive tract to change? Maybe the pig is an animal that, if properly selected, could handle a high fiber diet mcre like a ruminant than we have ever imagined."

The scientists are also asking the question: Is there any kind of a physiological connection between backfat thickness and the digestive differences between these lines, or was there a coincidental selection of genes for backfat thickness and genes for the other traits?

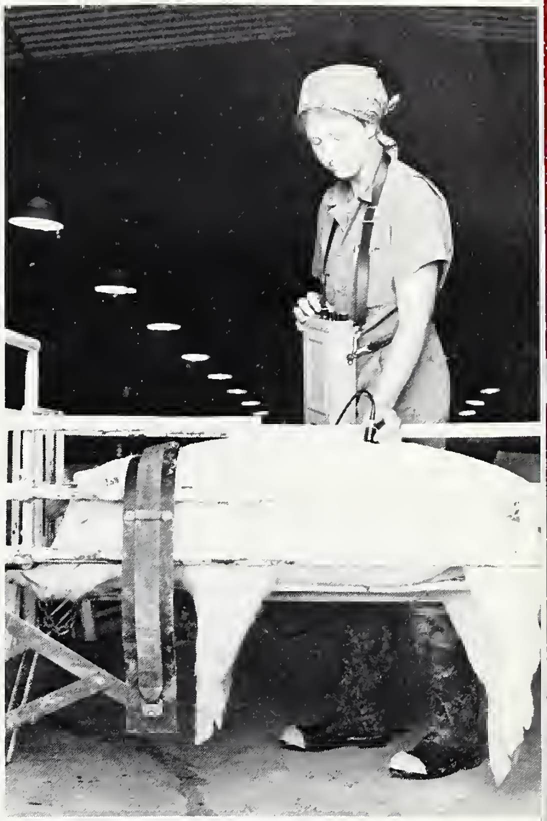
"We need to confirm that a heavy intestine is desirable," says Pekas. "It may be that through progeny testing we could find out whether a boar has the ability to transmit this heavy intestine trait to his offspring. I've already talked to our animal breeding people about that concept, and we are excited about such a prospect."

A sophisticated apparatus called an endoscope that was developed for studying the human digestive tract arrived at the Center this year for Pekas and his colleagues to use in meat animals studies. The endoscope is a flexible, 6-foot-long tube containing thousands of glass fibers through which images from the inside of the GI tract are transmitted to the eye or a microscope.

"We can connect a movie camera to the endoscope and explore the digestive tract visually in a way that we've never been able to do before in a live animal," says Pekas.

The endoscope has two hollow channels through which the scientists can pass instruments, a biopsy probe, for example. The 2-millimeter-wide biopsy probe has a sharp jaw that opens. Researchers can advance the biopsy probe to the intestinal lining called epithelium, snip off a sample, and bring out the sample within seconds for study outside the animal.

Throughout the animal's growth phase, the scientists can examine the effect that a change in diet may have on an animal's epithelial tissue.



Ultrasonic techniques to measure backfat—being tested by research technician Janell Dague—may someday provide data for evaluating fat and lean composition in live animals during various stages of growth. (0882X937-15)

"From a few animals we can harvest a lot of data that I think will be of more value than the data we might get from slaughtering 50 animals," says Pekas.

Studies in the laboratory animals have shown the epithelial cells of the intestinal surface are normally formed and shed into the gut once each day and are then available for digestion just like the food the animals ate, Pekas says. If this observation holds true in the pig, a large percentage of the total energy requirement of the pig is spent to replace these cells. It just may be that a genetically lean pig or any animal that performs in a superior way can perform its digestive functions with a lower turnover of cells and a lower turnover of energy.

Some scientists have theorized that antimicrobial feed additives that

normally stimulate growth in pigs may be effective partly because they somehow reduce the turnover of cells in the lining of the GI tract. Animal nutritionist J. T. Yen is studying the mechanism of action of this additive.

In related research, microbiologist Vincent H. Varel found that populations of microorganisms that break down cellulose do not become as numerous in the intestines of the obese pigs as they do in lean pigs.

Nutritionist Wilson G. Pond found that a diet marginally low in protein fed to the lean pigs early in their growth reduced their weight gain—an effect from which they never recovered.

In both lean and obese pigs Pekas has found a positive relationship between the weight of the small intestine and the rate and efficiency of body weight gain.

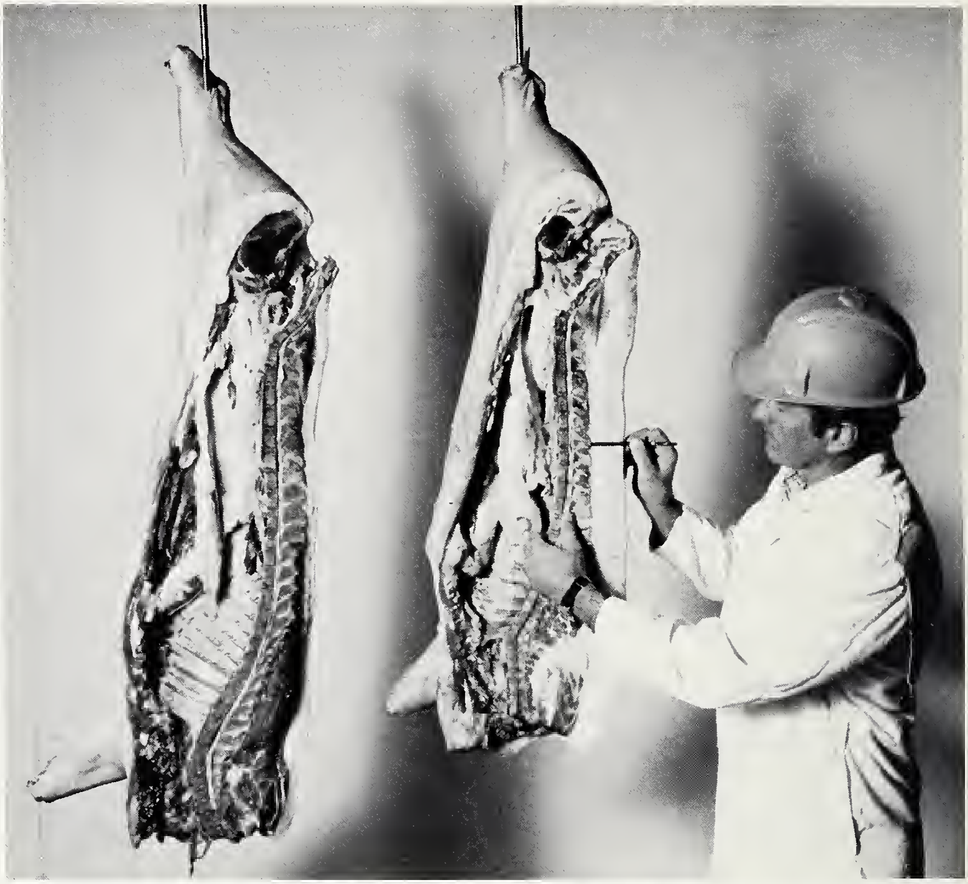
Another question that the scientists are addressing is whether or not we want to develop a pig that consumes more than ordinary amounts of feed over a short time so the extra amount of feed will go into production of edible meat rather than maintenance.

Until now, a study of this question has been difficult because, contrary to a popular notion, pigs have rigidly built-in appetite control. Pekas has developed a semiliquid combination of water and feed that he has fed through tubes placed into pigs' stomachs through surgical openings called fistulas.

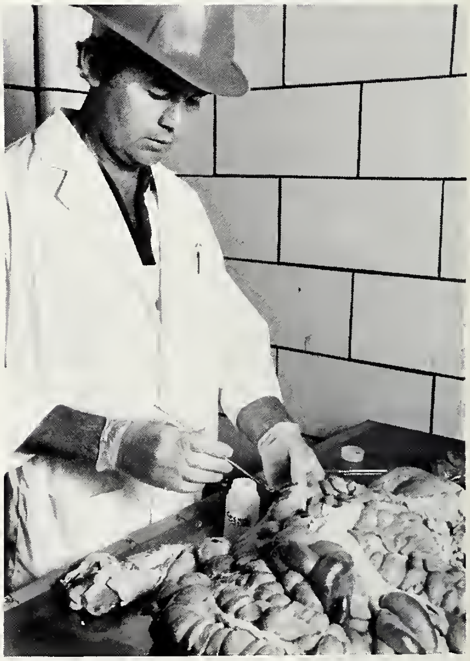
In one experiment he has found he can tube-feed pigs at normal feeding rates from weaning to market weight through the stomach fistulas. Pigs that were tube-fed only a portion of each day's meal were compared to pigs with fistulas that were not tube-fed and to pigs that had no surgery at all. The three groups of pigs consumed the same total amount of feed.

Now, the researcher will study the effects that overriding appetite has on the performance of lean and obese pigs.

"Here are some of the questions we're asking," says Pekas. "Is he really going to gain an extra increment of tissue and what is the type of tissue? Is it going to be muscle mass or is it going to be primarily fat? How does he derive this extra nutrient? Does he enlarge his GI tract? Does his stomach enlarge? his intestines? his colon? Does turnover of epithelial cells increase because he's got to crank his whole system up to accelerate the digestive process to handle this extra nutrient coming through? There are a lot of exciting questions, and I think through this study we're going to determine experimentally whether we can say yes indeed, there is a need to try to develop a strain of animals that has a super appetite.



Above: The carcass from a lean line of pigs (left) has little backfat compared to the carcass being measured by Pekas. (0882X935-10a)



Right: Microbiologist Vincent Varel takes tissue samples from gut contents of lean and obese swine for comparative counts of microorganisms that break down cellulose. Varel has found such organisms to be more numerous in lean pigs. (0882X939-21a)

Jerome C. Pekas is located at the Roman L. Hruska U.S. Meat Animal Research Center, P.O. Box 166, Clay Center, Nebr. 68933.—(By Ben Hardin, Peoria, Ill.)■

Pioneering Nitrogen Fixation

Scientists have grown tissue in culture from nodules on alfalfa plant roots as part of broad basic studies on understanding alfalfa's ability to capture nitrogen from the atmosphere for plant growth. It is believed to be the first time this has been accomplished.

The resulting tissue did not contain the bacterium, *Rhizobium meliloti*, known to associate symbiotically with the plant in nitrogen-fixation nodules, says Carroll P. Vance, ARS plant physiologist.

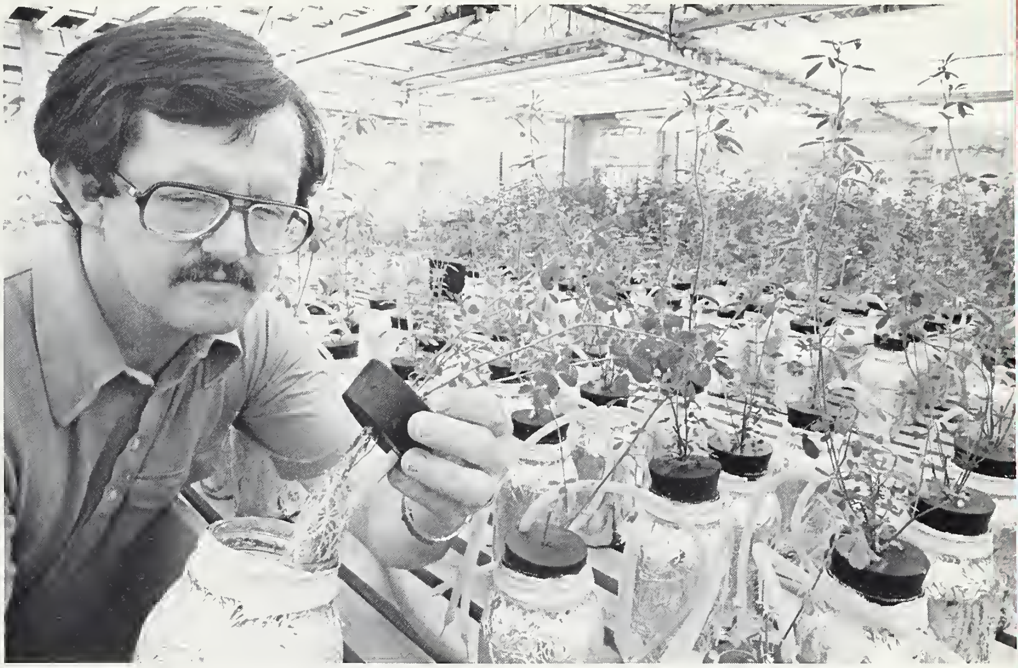
The tissue, taken from the meristem, or growth point of the nodule, was from two experimental alfalfa lines that form nodules but for unknown genetic reasons do not fix nitrogen. Vance and Lois E. B. Johnson, a plant pathologist, formerly with the University of Minnesota, were successful in growing tissue 80 percent of the time from one experimental alfalfa line and 30 percent from the other.

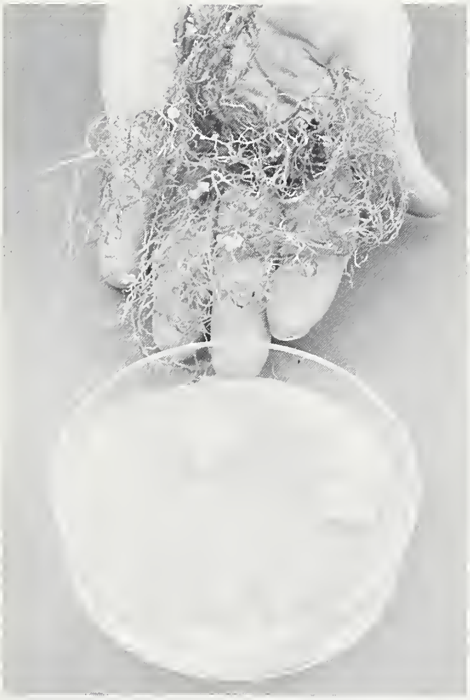
"Our research suggests," Vance says, "that Rhizobium bacteria are required for only limited periods during nodule initiation, and the bacteria may have no direct influence on subsequent structural changes and growth of the nodule." By selecting tissue from the meristem of the nodules, Vance and Johnson avoided the presence of Rhizobium bacteria and thus could culture and observe the growth of the tissue in the absence of the bacteria.

Vance then asks, "Does this absence suggest that the bacteria have incorporated their own DNA into alfalfa DNA to stimulate alfalfa cells to divide and enlarge to produce nodules?" DNA, or deoxyribonucleic acid, contains the genetic code and transmits the hereditary patterns for cell growth and differentiation.

Use of the cultured nodules will enable scientists to search for injected bacterial DNA in the nodule free of contamination by DNA from the whole bacteria.

"If further research determines that the Rhizobium DNA is incorporated into the plant DNA," Vance says, "then the prospect for genetically engineering nodule formation and nitrogen fixation in other crop species would be enhanced. This DNA transfer might also allow genetic engineering of a more productive nitrogen-fixing association between Rhizobium bacteria and the plant host."





Above: Representing a broad selection of nitrogen fixation potential, these alfalfa genotypes are grown in a liquid medium to provide plant physiologist Carroll Vance with a steady supply of root nodules for biochemical analysis. (0681X779-4)

Left: Tissue grown in culture from ineffective root nodules may reveal why certain alfalfa genotypes are incapable of nitrogen fixation. (0681X777-13)

Vance learned advanced research techniques to answer the question of DNA transfer on a fellowship this past summer at the Max Plank Institut, Koln, West Germany, and Marseille University, Marseille, France.

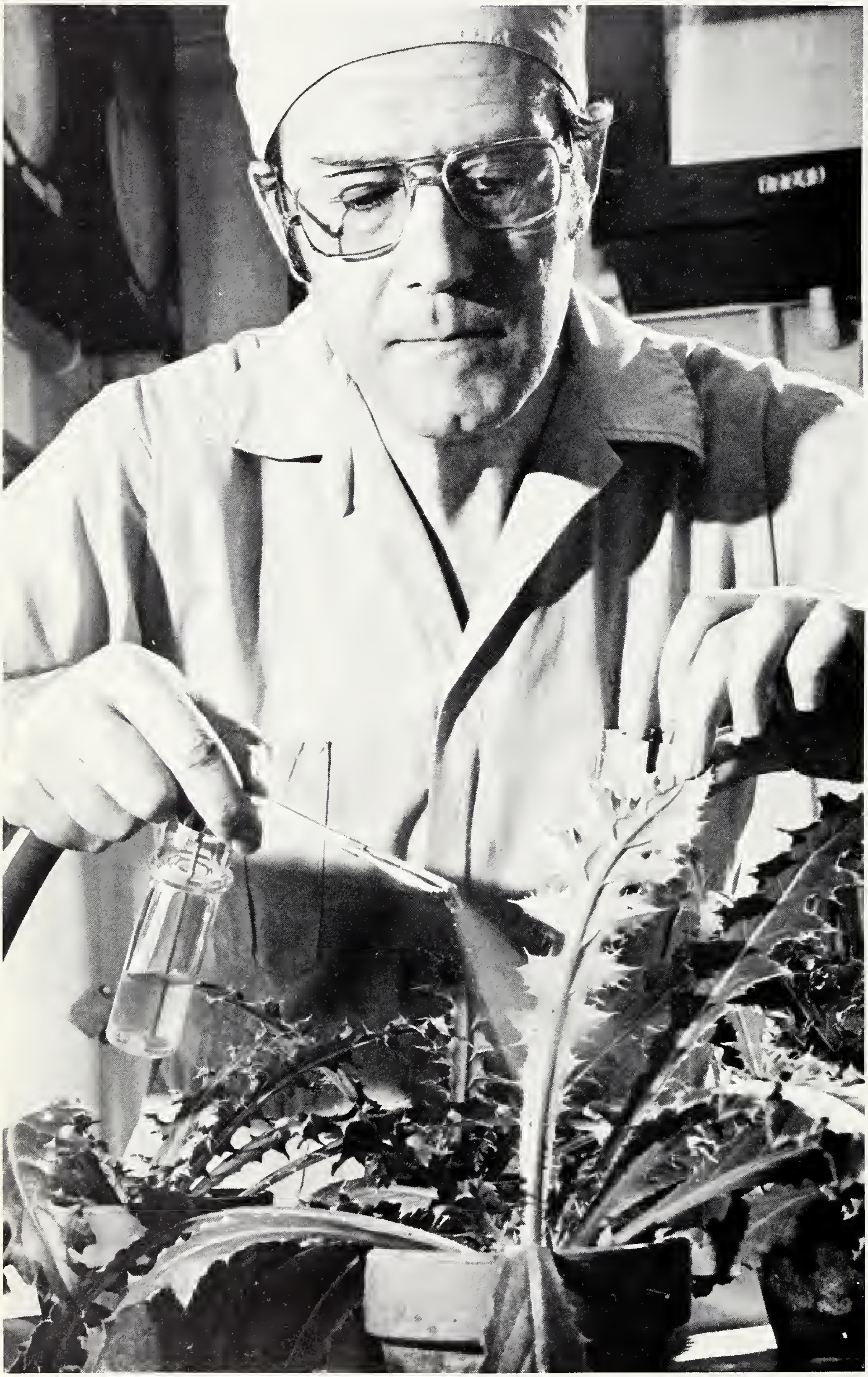
During the fellowship, sponsored by the Organization for Economic Cooperation and Development, Paris, France, he studied molecular techniques used to determine if bacterial DNA has been incorporated into plant DNA. In return, he taught scientists there the methods used to establish nodule tissue cultures.

Vance, Donald K. Barnes and Gary H. Heichel make up the nitrogen fixation research team that was awarded a USDA Science and Education director's plaque in May of 1982. The team was cited for its research on nitrogen fixation and host plant-Rhizobium interaction in forage legumes.

Team members discovered that nitrogen fixation is an inherited trait. They also discovered that the occurrence of effective strains of *Rhizobium* is greater in nodules of alfalfa populations selected for high levels of nitrogen fixation than in populations selected for low levels. The unit research leader is Gordon C. Marten.

Carroll P. Vance is located in Rm. 404, Agronomy Bldg., University of Minnesota, St. Paul, Minn. 55108.—(By Robert E. Enlow, Peoria, Ill.)■

Routing Weeds With Rusts



Plant pathologist Demetrios Politis applies an inoculum made from *Carduus* rust spores to a musk thistle to determine how effective this natural enemy is at debilitating its host. (0582W282-35)

In Montana and adjacent states, millions of rangeland acres are becoming a wasteland of poisonous leafy spurge, an invading Eurasian weed.

In the Midwest, European musk thistle is a threat to the pastures and fall-sown grain fields of Iowa, Kansas, and Missouri.

California growers of barley and other small grains, meanwhile, are waging an uncertain war against yellow starthistle, another serious new pest.

Each year, noxious weeds cut U.S. crop yields, reduce use of rangelands and pastures, and cost millions of dollars in weed control measures. Most of the culprits, ironically, are not native North American weeds at all, but species accidentally introduced from other countries. Having left their natural enemies behind, these exotic plants often spread unhindered through U.S. crop and pasture land, especially where conventional herbicide and tillage control measures prove inadequate or infeasible.

The weeds' foreign origins, however, are providing a means of control. Leafy spurge *(Euphorbia esula-virgata)*, curly dock *(Rumex crispus)*, yellow starthistle *(Centaurea solstitialis L.)*, musk thistle *(Carduus nutans L.)*, and other serious weeds are being reunited with their disease-causing enemies at the ARS Plant Disease Research Laboratory in Frederick, Md. Plant pathologist William L. Bruckart, biologist Dennis R. Johnson, and project associates Demetrios J. Politis and Sherry K. Turner are importing pathogenic rust fungi to the Frederick quarantine facility to test them for possible release as biological weed controls.

A rust introduced into the environment should markedly reduce the infestation of a particular weed for years to come, according to the four scientists.

For ranchers and farmers who find herbicides and cultivation too expensive or infeasible, biological control may mark the difference between productive and virtually useless land.

This is the case in the spurge-infested areas of Montana, the North

Central states, and Canadian provinces. Leafy spurge was inadvertently introduced with alfalfa seed onto a ranch in Montana's Judith Basin in 1929. Little attention was paid.

Today, Judith Basin has 27,000 acres of the weed, which cattle will not eat. The entire state has well over a half-million acres of spurge, annually costing Montana ranchers an estimated $2.5 million to control. The rough terrain and relatively low economic return on rangeland make the problem extremely difficult to control by conventional methods.

Introducing a pathogen that attacks only the target weed and that needs to be applied only once would be ideal in these circumstances. At Frederick, that is exactly what Bruckart and his colleagues have begun to accomplish.

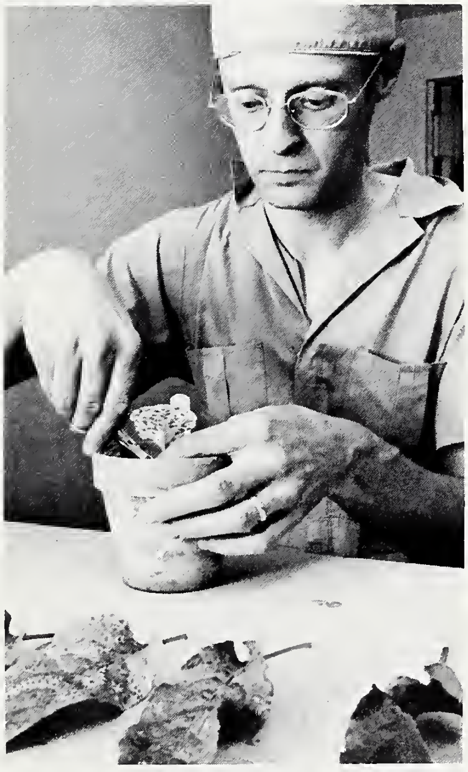
After being gathered as dried spores or infected plant parts in the countries where they coevolved with our exotic weeds, the fungal pathogens are shipped to Frederick and stored in liquid nitrogen. Then begins the patient process of evaluating and screening to discover which fungi are the most deadly to spurge, thistle, and other noxious plants but do not represent a threat to crops and other desired flora.

The process is complicated by the fact that both pathogens and weeds of particular species exist in many regional varieties, or ecotypes, according to Bruckart. Leafy spurge, for example, is not a single species of plant, but a name used to encompass a variety of closely related plant types which compound the problems of control. Similarly, the pathogenic fungi also differ greatly within their general groupings.

Thus, a rust that decimates leafy spurge in Montana may have little or no effect on spurge in Minnesota, says Demetrios Politis, whose yellow starthistle research is funded by the State of California.

"Once a promising isolate of fungus is identified, it must be tested on at least 56 closely related and economically important plants," says Sherry Turner, who studies leafy spurge on a cooperative grant from Montana State University. "We can't introduce a rust that attacks crops as well as weeds."

Musk thistle leaf infected with Carduus rust—a plant pathogen imported from Turkey for testing for possible use as a specific musk thistle control agent. (0582W488-4a)



Rust disease on curly dock is studied by plant pathologist William Bruckart (left) (0582W485-16a), who quantifies different amounts of infection by counting pustules within the artificial rings marked on each leaf (above). (0582W484-26)

Above: Confining microscopic pathogens to USDA's Plant Disease Research Laboratory in Frederick, Md., requires negative pressure greenhouses where the air flows in, not out—plus strict controls on entering and leaving the greenhouse area. (0482W360-18a)

Fortunately, most rusts are host specific and will not attack plants other than their weed host. Yet because of the potential risk in bringing unknown plant pathogens into the United States, physical security at the Plant Disease Lab is tight. The Frederick lab, in fact, is the only USDA facility authorized by APHIS (Animal and Plant Health Inspection Service), to import such agents.

Turner and her colleagues work in double-walled, containment greenhouses kept under slightly negative pressure (air flows *in,* not out) to prevent fungus spores from escaping. Scientists entering the greenhouses must don gowns and caps similar to those worn by hospital doctors. Personnel exit through a shower, and all materials leaving the greenhouse must be sterilized beforehand.

Biological control's potential for success, however, eases the tedium of these necessary procedures. Frederick scientists, led by R. G. Emge (now retired), recently used an introduced rust to decimate Eurasian rush skeleton weed *(Chondrilla juncea),* a serious wheatland pest in the Pacific Northwest.

Following the lead of Australian scientists at the Commonwealth Science & Industrial Research Organization in France and Australia, the Frederick scientists isolated a potent strain of the exotic fungus *Puccinia chondrillina* and applied it to skeleton weed in greenhouse and field tests at the approximate rate of 1 gram (about 0.4 ounces) of spores per acre. The results were astounding.

According to a 1981 *Phytopathology* article by Emge and colleagues J. Stanley Melching and C. H. Kingsolver, rusted skeleton weed produced 65 percent fewer seeds the first year and 94 percent fewer the second year. During the second season, two-thirds of the rusted plants died prematurely. And this weed control resulted from only one application of the fungus.

"We are very encouraged by the results so far," says William M. Dowler, chief of the Plant Disease Laboratory. "Work underway now should lead to equally significant improvements in the control of leafy spurge, thistle, and other noxious weeds."

"William L. Bruckart and other members of the research team are located at the Plant Disease Research Laboratory, P.O. Box 1209, Frederick, Md. 21701.—(By Andrew Walker, Beltsville, Md.)■

Trace Element Research in Human Nutrition

Laboratory rats, the subjects of a nutritional study on liver disease, were having difficulty in metabolizing sugar in their highly purified diets. The year was 1954. Walter Mertz and colleague Klaus Schwarz, both then working at the U.S. National Institutes of Health, discovered that brewer's yeast or powdered pork kidney would cure the disorder when fed with the otherwise balanced diets. Five years later, they identified the trace element chromium as the factor responsible for this effect.

Mertz, now Director of the Agricultural Research Service's Human Nutrition Research Center, says that later research has shown that chromium is an essential trace element for humans also. Insulin, which is produced in the body to metabolize glucose, appears to require chromium to activate it. Studies of middle-aged and elderly people with impaired glucose tolerance showed that a third to a half of them improved after taking a chromium supplement. More recent studies demonstrated a reduction in blood cholesterol levels after taking inorganic chromium or a high-chromium brewer's yeast.

Until recent progress was made in technology to measure chromium in body fluids, however, a chromium deficiency could not be accurately detected by chemical analysis. (See "Scrap the Old Chromium Data," next page.) Chromium and many other elements are normally present in such small amounts that they cannot be easily measured. Early scientists named them "trace elements" because only traces showed up in analysis of body fluids or tissue.

What Mertz refers to as "the new trace elements"—lead, arsenic, nickel, silicon, zinc, and vanadium—have mostly been identified since 1970. Their discovery was possible only because of the development of the "ultra-clean environment" for laboratory animals.

Zinc deficiency may be the second most significant dietary problem in the United States, after inadequate iron, Mertz says. Zinc deficiencies have been implicated in growth problems with children in some parts of Colorado and in a few foreign countries, notably Iran.

Generally, a human zinc deficiency is related to unusual diets that contain zinc in a form that is not easily utilized.

In other studies, researchers have found that deficiencies of silicon have caused severe bone deformities, particularly of the skull, during growth of chicks and rats. Silicon is believed to be necessary for bone growth in humans also, but the "safe and adequate" amount required for health is unknown.

Not all trace element knowledge is new, Mertz notes. Iron and iodine, for example, have been known for scores of years to be essential. A deficiency of iron leads to anemia while insufficient iodine causes goiter, an enlargement of the thyroid gland.

On the other hand, Mertz refers to a growing concern voiced by the Food and Nutrition Board of the National Academy of Sciences about the amount of iodine entering the human food chain from non-nutritional sources. These sources include disinfectants, some coloring agents, and bread dough conditioners. Too much iodine can also lead to goiter, Mertz says.

Several trace elements—lead, arsenic, and selenium—used to be known only for their poisonous effects, leading Mertz to warn against trying to supplement one's own diet with specific trace minerals. In addition to some elements being harmful except in the most minute amounts, many tend to interact with each other.

Vitamin C, for example, makes dietary iron more available to the body while depressing the amount of copper available. In laboratory tests, vitamin C almost blocks selenium absorption.

Mertz notes that there are a few foods that are particularly good sources for certain trace elements. Oysters are high in zinc and nuts high in copper. Cereal grains provide most of the trace elements if the whole grain is eaten. Eating a wide variety of whole foods leads to a better balance of all nutrients, not just the trace elements, Mertz says.

Walter Mertz is director of the Beltsville Human Nutrition Research Center, Bldg. 308, BARC-East, Beltsville, Md. 20705.—(By Lloyd McLaughlin, Beltsville, Md.)■

Scrap the Old Chromium Data

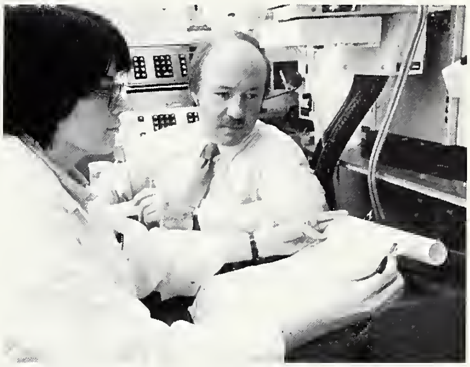
A new technique has been used to prove that measurements of chromium in normal body fluids made before 1978 are ten times too high. The amount of chromium in body fluids has been a guide for recommendations of the amount of chromium to be included in the diet. Chromium is an essential trace element for humans; it is necessary for the normal action of insulin.

In 1978, ARS research chemist Claude Veillon found that the commonly used method for determining the amount of chromium in urine (furnace atomic absorption spectrometry) was not accurately measuring the chromium content of the samples. Veillon, working with Barbara E. Guthrie from Otago University, Dunedin, New Zealand, and ARS research chemist Wayne R. Wolf, found that this method was measuring only background noise.

By using new equipment called a wavelength-modulated-atomic-absorption-spectrometer, Veillon and colleagues discovered that the amount of chromium in normal blood and urine is in the range of 0.3 parts per billion (ppb). Previous measurements of chromium in body fluids had shown 3 to 33 ppb. "An entire field of study must begin anew," said Veillon, "since measurements of chromium in urine or blood serum taken before 1978 are probably useless."

Veillon's work ended years of speculation by nutritionists about why so much chromium from foods was absorbed by the body and excreted by way of the urine. Since so much of the chromium from the diet seemed to show up in the urine, nutritionists had thought that certain forms of chromium were more easily absorbed by the body. Now, it is apparent that very little of the chromium was actually absorbed into the body.

It is difficult to measure the chromium content of body fluids because these liquids are very complex. They contain relatively little chromium compared to other materials which can cloud the measurements. Much of the equipment formerly used to measure chromium could not adequately separate out the chromium.



Improved techniques in atomic absorption spectometry provide chemists Kristine Patterson and Claude Veillon with revised data on the amount of dietary chromium absorbed by the body. (0282W137-26a)

Now that the normal ranges are known, older equipment can be adjusted to measure correctly the chromium content of body fluids. Or the new generation atomic absorption spectrometers can be used, since they are capable of making the background corrections that are necessary, Veillon said.

Overexposure to chromium may result in increased risk of respiratory cancer, ulceration of the skin, and kidney damage to workers who are involved in the plating, welding, or processing of ore. If urine testing was used to evaluate the amount of exposure to chromium, any conclusions or standards based on these measurements are no longer useful, Veillon observed.

Claude Veillon is located in Rm. 215, Bldg. 307, and Wayne R. Wolf is located in Rm. 231, Bldg. 308, Beltsville Agricultural Research Center-East, Beltsville, Md. 20705.—(By Ellen Mika, Beltsville, Md.)■

Plant-Produced Chemicals Play Many Roles

Although natural product chemists have been fascinated for more than 100 years by the enormous and complicated array of end products that plants produce, only in the past 30 years have scientists discovered the biological function of some of these.

One group of plant-produced biochemicals—isopentenoids—has particularly intrigued scientists. Isopentenoids, characterized by a common building block (isopentene), function as plant growth regulators, toxins, insect attractants, and feeding deterrants. Some isopentenoids, such as carotene found in certain vegetables, are important components in human nutrition.

A symposium on the chemistry and function of isopentenoids in plants was held earlier this year at the Western Regional Research Center, Berkeley, California.

Arranged by ARS chemists W. David Nes, Glenn Fuller, and Lee S. Tsai, the symposium brought together scientists from 6 ARS locations, 17 universities, 4 foreign countries, and private industry to exchange research findings, plan for future studies, and build communication channels for future exchanges.

"Research on isopentenoids and related compounds benefits more than agriculture. The basic information gained often helps scientists who are solving problems in the fields of chemistry, biochemistry, and human medicine and endocrinology, just to name a few," says ARS chemist Malcolm Thompson, Beltsville, Md., keynote speaker at the symposium. "Understanding the basic mechanisms of how plants interact with insects, mammals, fungi, environment, and other plants is an awesome task. This research challenge is far more complex than examining only chemical reactions that occur in mammals; yet mammals, especially humans, are affected by the increase or decrease in food supply caused by isopentenoids."

Scientists are approaching this challenge by focusing on five basic interactions: plant/insect; plant/mammal; plant/plant; plant/fungi; and plant/environment. The following research briefs outline some of the work being done in these categories.

Chemist Leslie M. McDonough, Yakima, Wash., found two isopentenoids in plants, called Precocene I and II, that cause premature metamorphosis of insect larvae, creating miniature adults that die quickly and cannot reproduce. Many analogues and derivatives of these hormones have been synthesized for possible use in insect control programs.

Insects require sterols for normal reproduction, metabolism, and formation of their structure. Because many of them cannot manufacture sterols in their bodies, they obtain them from the plants that they attack. According to entomologist James A. Svoboda, Beltsville, Md., there is a marked difference in sterols required by various insects, and these differences might be exploited to develop new, safe, highly selective pesticides for the future.

Many isopentenoids are responsible for the aroma of fruits, vegetables, and other plants. At the Western Regional Research Center (WRRC), Berkeley, Calif., Ronald G. Buttery has been looking into the formation of these aroma compounds and how they may attract insects to certain plants. Further investigation may permit chemists to duplicate these compounds, or some related form of the compounds, and use them to bait traps that will lure insects away from valuable food and feed crops.

Stanley Osman, a chemist at the Eastern Regional Research Center, Philadelphia, Pa., has been concerned with the possibility that glycoalkaloids produced by plants such as tomatoes and potatoes may be important in disease resistance. However, as Osman points out, glycoalkaloids can be toxic to humans if they occur in great enough concentrations. Therefore plant breeders will probably not be able to increase the concentration of these compounds in commercially valuable species of this plant family.

Scientists for many years believed that cholesterol was found only in animals, but the substance has been detected in potatoes and other crops. "Cholesterol is a universal component in both plant and animal kingdoms, being metabolized to such sterol hormones as mammalian estrogens. These hormones regulate the reproductive cycle in animals and are believed by some persons to regulate flowering in plants," says chemist Erich Heftmann, WRRC.

Richard F. Keeler reports studies that suggest some of the steroidal alkaloids in range weeds and some crop plants may cause malformations in animals.

Russian knapweed (*Centaurea repens*) and yellow starthistle (*Centaurea solstitialis*) both range weeds, produce sesquiterpene lactones which can be toxic to range animals and wildlife. Kenneth L. Stevens, WRRC, has identified more than 15 of these compounds by modern spectroscopic techniques. The lactones had previously been found in other plants and were shown to be toxic to animals. Medical researchers are now testing some of these compounds for possible anticancer properties.

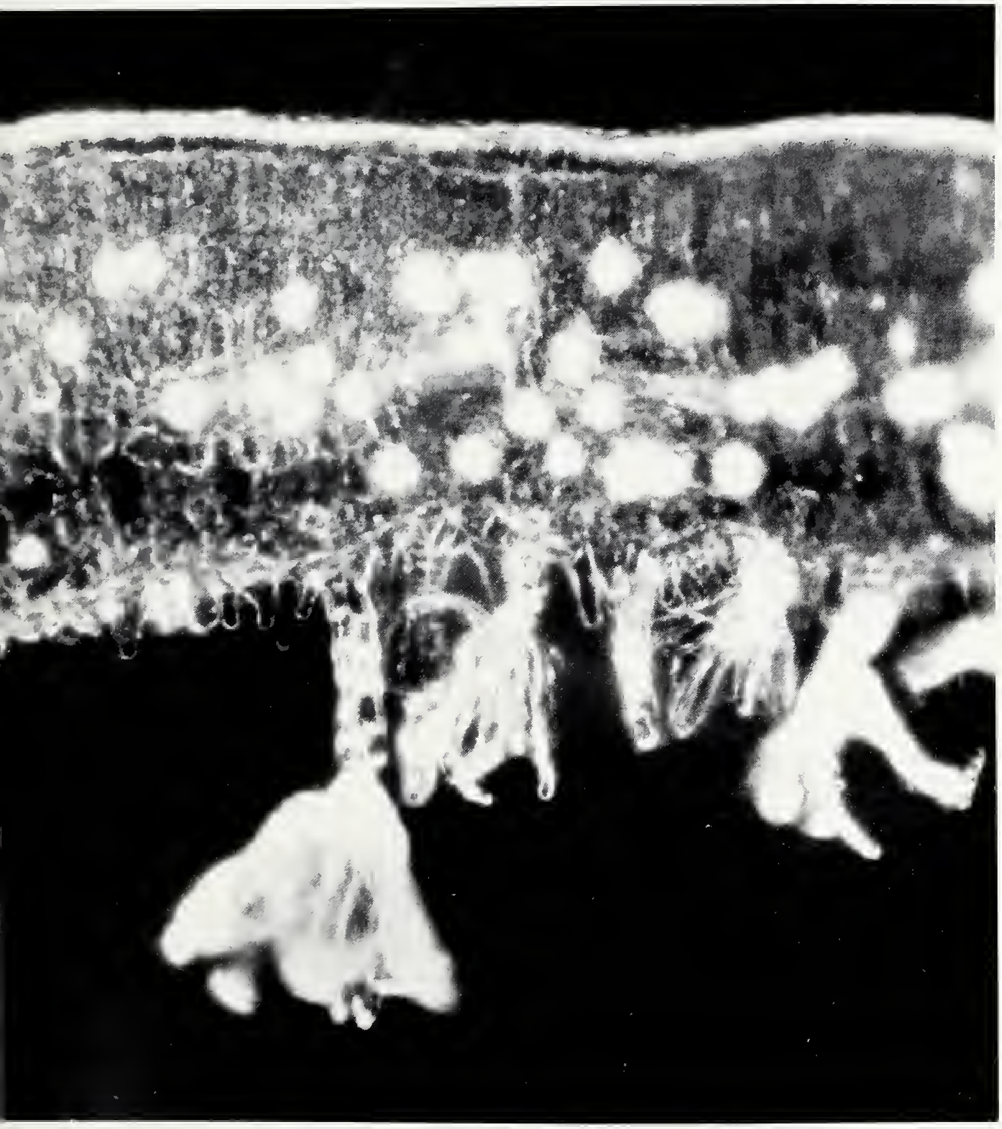
Other research by Kenneth L. Stevens shows how the sesquiterpene lactones in Russian knapweed and yellow starthistle inhibit the growth of other plants growing in the vicinity of these weeds.

Steroids and other types of isopentenoids control the life cycle of some fungi. W. David Nes, WRRC, presented evidence which showed that some types of isopentenoids induce a beneficial effect on the growth and reproduction of *Phytophthora* species while other isopentenoids inhibit reproduction.

In limited greenhouse and field trials, brassinosteroids—in the isopentenoid group—considerably increased biomass production and crop yields of a few vegetables when applied to their green leaves. Yields of treated radishes and lettuce increased 15 to 30 percent over the yields of untreated plants.

W. David Nes, Glenn Fuller, and Lee S. Tsai are located at the Western Regional Research Center, 800 Buchanan St., Berkeley, Calif. 94710.—(By Dennis Senft, Oakland, Calif.)■

Rhododendron Weevil Repellents



A cross section of a weevil-repellent rhododendron leaf exhibits the glandular scales on the leaf's underside that may be the source of weevil-repellent chemical compounds. (PN-7027)

The secret behind the resistance of some rhododendron varieties to weevils has been identified, and the knowledge could play a role in future weevil control programs for all plants.

ARS plant physiologist Robert P. Doss, Puyallup, Wash., and coworkers at the University of Washington in Seattle have found that resistant rhododendron varieties, unlike susceptible varieties, secrete volatile chemical compounds called terpenes that repel weevils. One of these terpenes, germacrone, is powerful enough to override even as strong a weevil-feeding stimulant as table sugar.

Adult weevils feed on rhododendron leaves, causing unsightly damage. Females lay their eggs on the plant and the resulting root-eating larvae can kill pot-grown plants in nurseries. Investigations into rhododendron resistance to weevils began after growers in the Pacific Northwest claimed that the insects fed heavily on some varieties but left other varieties in the same field virtually untouched.

Studies established that rhododendrons featuring glandular scales on their leaves (lepidotes) do indeed exhibit a general resistance to weevil feeding, whereas those without scales (elepidotes) do not.

To determine the source of this resistance, Doss and coworkers tested leaf extracts from resistant and susceptible varieties on the obscure root weevil, which, despite its name, is the most common and worst rhododendron pest in the Northwest.

Leaf extracts were tested on small discs of weevil-feeding material treated with sucrose and common table sugar to stimulate weevil appetites. In nearly every case, extracts from resistant, scaled rhododendrons prevented weevils from feeding on the discs, whereas extracts from nonscaled rhododendrons increased feeding to even greater levels than when no extracts were placed on the discs.

"The results suggest that the lepidote rhododendrons owe their resistance to the production and secretion of volatile repellents such as germacrone, probably from their glandular leaf scales," says Doss.

Although resistant scaled rhododendrons cannot be crossbred with susceptible nonscaled varieties, Doss says that the techniques used to identify germacrone and other terpenes should make it easier for breeders in the future to screen new selections for weevil resistance.

More important, perhaps, there is the possibility that slow-release formulations of terpenes could be developed. Acting as biological repellents, these formulations could be sprayed on susceptible rhododendron varieties or on any other plant that weevils feed on.

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